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AUTOMATIC TARGETING DEVICE IN SUPPORT OF THE XM188/XM230 DATA ACQUISITION TEST (DAT)

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FINAL REPORT

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This report covers the development and operating procedure for a computer operated automatic targeting device. This device automatically obtains and outputs both dispersion coordinates and velocities for an automatic weapon in bursts up to 60 rounds. The chronological order of rounds is maintained. Statistics on dispersion and accuracy, if point of aim is input to the computer, is also output. Accuracy of this system, with 50% probability, is within ± 1/2 inch from actual location at 1,000 inches firing 20 rounds.

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ABSTRACT

This report covers the development and operating procedures for a computer operated automatic targeting device. The device consists of (16) ballistic screens, (3) chronographs, a teletype, and a PDP 8/E computer. The ballistic screens are ordered in parallel and present a 6 x 6 ft. area and 4 planes to the projectile. With these four planes, the X and Y position and velocity of each round is obtained by trigonometry. Further computer calculations obtain statistics on the dispersion. The same statistics can be obtained for accuracy, if a point of aim is input to the computer. Listing of the coordinates of each round, in chronological order, can be obtained from any reference point, the default point being the center of impact. A graphical plot of the rounds may also be printed on the teletype. The high, low, and average velocity may be output from the computer program, or each individual round may be obtained on command. Due to the 8K core computer limitation, the present program will handle a maximum of 60 rounds per burst. The program is written in Digital Equipment Corporation's (DEC) FOCAL-8 language with PAL III assembly language overlay. This program may be operated in automatic or interactive command mode.

This device was developed in support of the XM188/XM230 Data Acquisition Test. As such, the system accuracy can only be stated with respect to 30MM rounds. The round position for a 20 round burst is within ± 1/2 inch at 1,000 inches. This accuracy is stated at a

50% confidence level. Erroneous ballistic screen outputs are usually of large magnitude. The program will trap these errors and delete the respective rounds from its computations. This input error is dependent on ballistic screen adjustment and sensitivity; however, under existing conditions this correctable error averages only 3 to 4 rounds per 300 rounds fired.

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I. OBJECTIVE

The objective of this effort was to reduce the time required in determining accuracy and dispersion of automatic weapons during engineering tests. The task was to be accomplished using as much existing equipment as possible and to computerize the process so that tabular and graphical data would be available after each burst.

II. GENERAL

A Digital Equipment Corporation PDP 8/E computer, 3 chronographs, teletype (Figure 1), and 16 ballistic screens (Figure 2) were used to accomplish the objective. A detailed list of equipment used is contained in Appendix D. The PDP 8/E was selected because it was in inventory, and relatively easy to interface. The velocity screens were chosen over other methods because of existing ballistic screen technology. The screens were arranged in a particular geometric pattern to enable measurement of both velocities and dispersion of the rounds fired from weapons being tested. The screens were positioned downrange from the test weapon as shown in Figure 3. Computer printed circuit boards were procured and modified to provide the capability desired. An external ballistic program (See Appendix A page A-15) was used to calculate an effective muzzle velocity from the velocity received downrange.

FIGURE 1. TELETYPE, COMPUTER, AND CHRONOGRAPHS

FIGURE 2. FRONT VIEW OF VELOCITY SCREENS

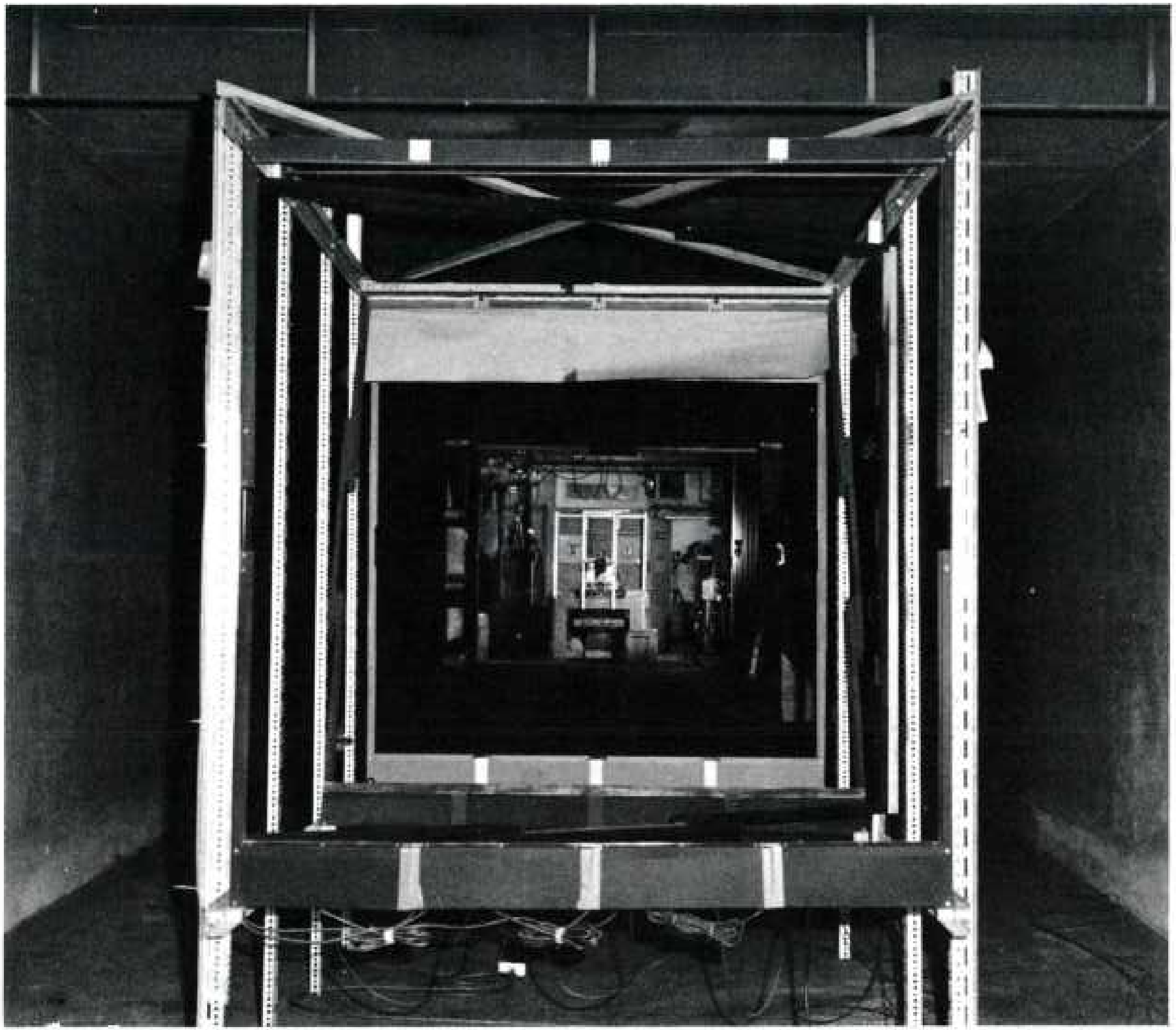


FIGURE 3. AFT VIEW OF VELOCITY SCREENS SET UP AT 1,000 INCHES

III. PRINCIPLE OF OPERATION

The 16 ballistic screens were oriented as shown in Figures 2 and 3 forming 30-60-90 degree triangles and four planes. As the projectiles decrease the light input to the light sensing diodes (Oehler model 55 ballistic screens), a 12v square wave with a rise time of 0.1 microsecond is produced. All four screens in one plane are connected in parallel to provide one output per plane. Screen one (first plane) starts all three chronographs and screens two, three, and four (remaining planes) stop their respective chronographs (See Figure 4).

The interface between the chronographs and the computer works in a hand-shake method. The chronographs sets a print line when its Binary Coded Decimal (BCD) data is stable telling the computer to read the BCD data from its respective two input/output devices. The computer then sends a read-down line signal to reset the chronograph. Two one-shot devices were required on the interface boards per chronograph to convert the normally high and low lines to pulses. A 112 nanosecond pulse was used for the print command and a 240 microsecond pulse was used for the read-done command to double-safe possible timing problems.

The computer continues in this method of dumping BCD data into core until a maximum of 60 rounds are fired or a programmable time between rounds is exceeded. Either the number of rounds in the burst, or an error message stating core has been exceeded, is then printed

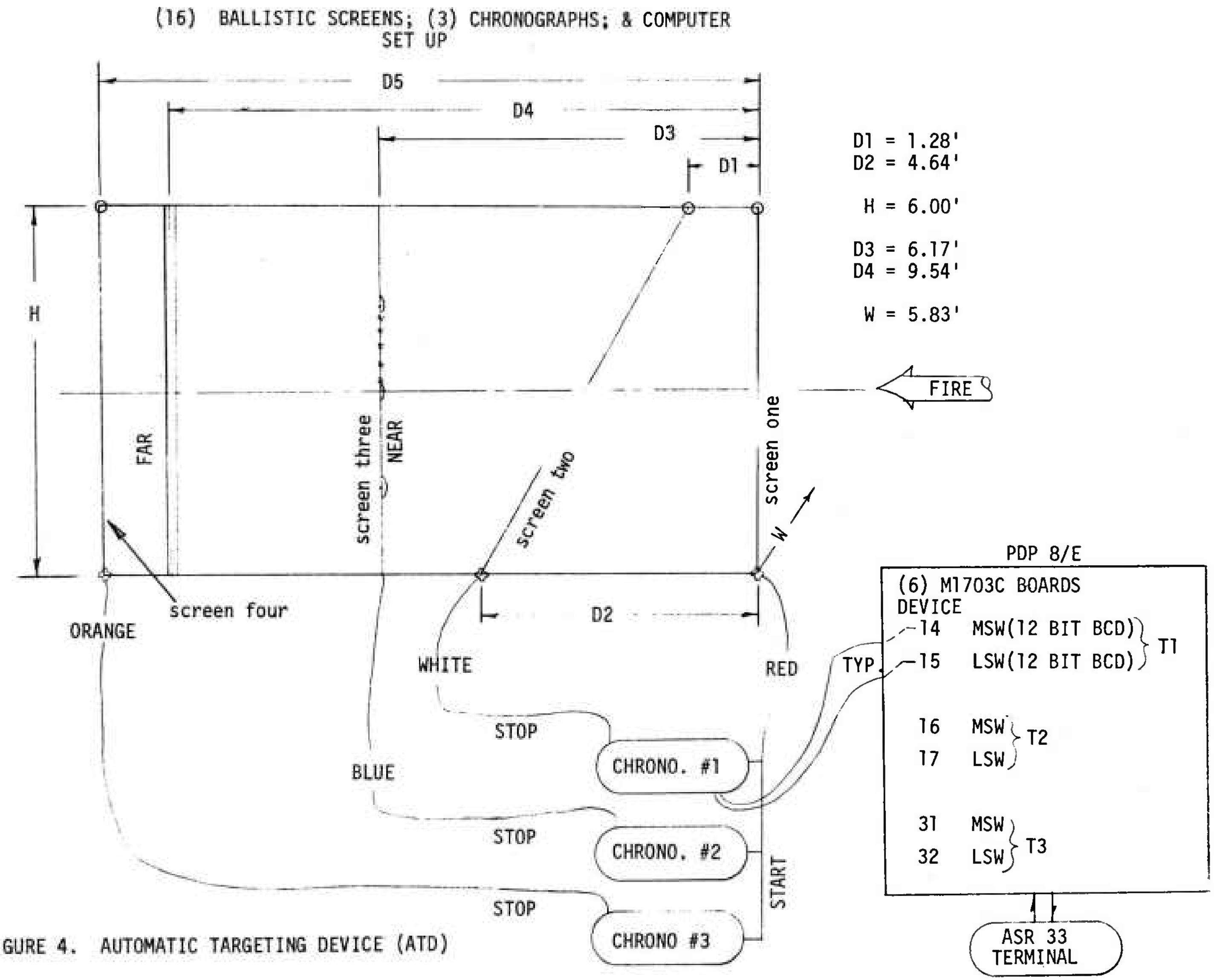


FIGURE 4. AUTOMATIC TARGETING DEVICE (ATD)

on the ASR (teletype). The assembly language program designated FN performs this operation. N = FN(-L) is the form of this subroutine where N is the number of rounds fired and L = 60, the maximum rounds per burst in this configuration. With extended core, L may be increased. Due to core limitation, only the BCD of the time and its pointers are retained in the computer, other variables are calculated each time they are used. To retrieve the BCD chronograph times in FOCAL floating point (3 words per variable), the assembly language subroutine FT(N,CR) is used where N is the round number and CR is the chronograph number.

To calculate the displacement, first the computer calculates the velocity for the respective round by V = D5/T3 (See Figure 4 for symbols). The time to the first possible "Y" location for this round is YFT = D1/V, the time to the last possible "Y" location is YLT = D2/V, using similar triangles the following proportionality holds:

Y : H as

(T1-YFT) : (YLT-YFT)

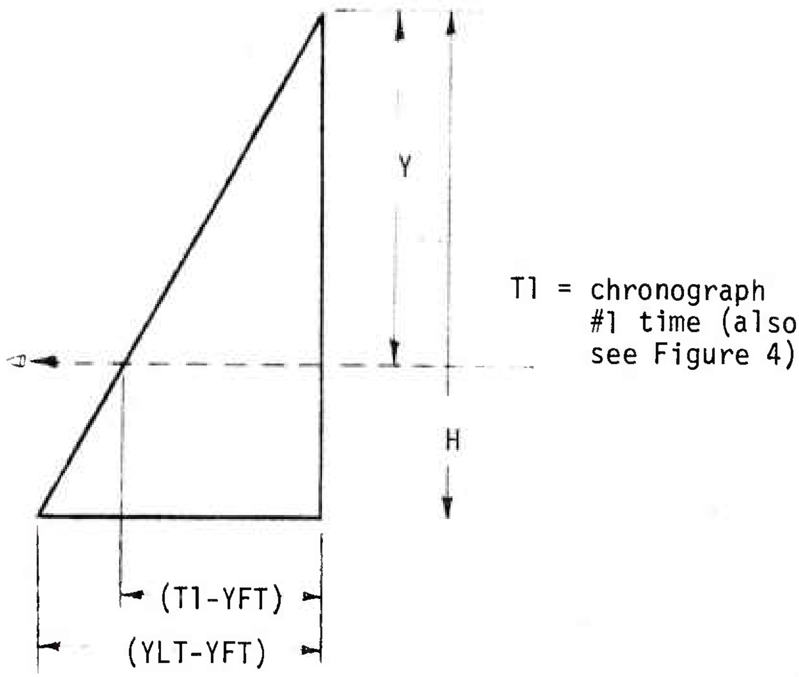


FIGURE 5. TIME/DISPLACEMENT RELATIONSHIP FOR "Y"

From the above, by substitution, the resulting equation for Y is as follows:

$$Y = H\{(D5 \cdot T1 - D1 \cdot T3) \div (D2 \cdot T3 - D1 \cdot T3)\}$$

The program may be operated either in automatic or command mode by setting variable switch AZ = 101 or 0 respectively. The commands are shown and explained in the command mode of the FOCAL program (See Group 23, Appendix A, page A-5).

The major area of concern in this device is the character of the signal between the ballistic screens and the chronographs (See Appendix C). With the chronograph in start and stop mode instead of

common mode, the chronographs themselves act as one-shots. That is, only the first start pulse of many is used while the respective chronograph is stopped and only the first stop is used while the chronograph is running. Therefore, many erroneous pulses noted in Appendix C are eliminated by the chronograph counters. Sensitivity and pulse width of the ballistic screens (Oehler Research) can be adjusted with two 25 turn potentiometers (i.e., two on each of the 16 screens). As can be seen in Appendix C, the sensitivity adjustment is critical (See System Accuracy, Section IV, for reasons). These ballistic screens are the weakest link in this system. With the 30MM, only 50,000 rounds were fired before more than 8 of the screens required replacement or were disconnected because of erroneous output (excessive pulses). This low life and reliability can be explained by the excessive abuse the 30MM round delivers in the confined ballistic screen location. Sonic shock, floor vibration and expelled propellant and debris encountered were reduced by additions to the set up shown in Figures 2 and 3. The 15 feet square firing bay does not allow firing shocks to dissipate as rapidly as desired. The affect of these set up changes was noticeable on ballistic screen reliability; however, their life was still considered marginal. These modifications consisted of sound insulating material draped along the sides of the screens to break up shock waves bouncing off the range walls. A plywood shield was placed between the weapon, and the screens to break up the shock wave and reduce the propellant

and debris flow through the screens. Finally, rubber and foam pads were placed under the screens feet to reduce vibration transfer from the floor to the screens.

The extended distance and angle limitations from the illuminiline to the light sensitive diodes were not covered in the manufacturer's literature and were considered major factors in screen life.

Even with all the problems encountered, the time saved in reducing targets is well worth the effort. The time to set up, retrieve, and reduce a 10 round color coded paper target to the statistics presented by the computer is estimated to be 40 minutes and require 3 to 4 people. With the aid of a digitizing table and computer, this time is reduced to approximately 20 minutes. With the Automatic Targeting Device, this process takes less than 2 minutes and requires only one person to accomplish the work. The time savings is, therefore, estimated at 2,000% or 20 times faster.

IV. SYSTEM ACCURACY

A. FACTORS AFFECTING SYSTEM ERROR

PROGRAM PARAMETERS

D1, D2, and H are the programming parameters that affect the "Y" coordinate calculations (See Figure 4) where:

H - height of the screen

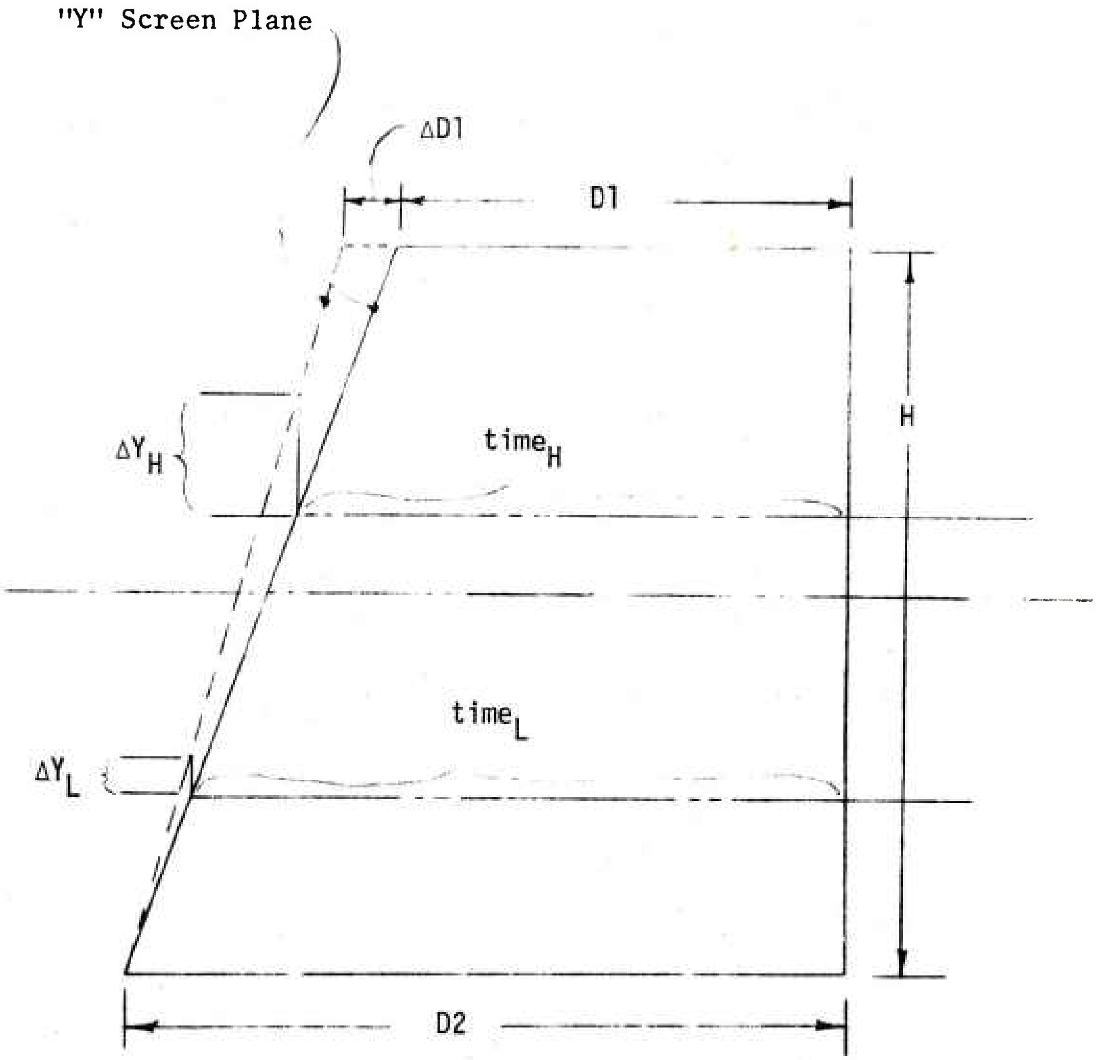
D1 - top distance to "Y" detecting screen from start screen

D2 - bottom distance to "Y" screen from start screen.

The DEC PDP 8/E must have six M1703C input boards and FOCAL programming available for the PDP 8/E in order to have the capability to work the problem.

The three parameters (H, D1, and D2), therefore, establish the effective angle the "Y" detecting screen is to the line of fire.

Increasing H will increase the extreme vertical spread evenly, while increasing D1 will spread the upper half of the target area rounds more than the lower half and increasing D2 will spread the lower half more than the upper half. This is shown in Figure 6. D3, D4, and W for "X" are similar to the "Y" parameters; however, an error is introduced because D3 and D4 are larger than D1 and D2. Since D3 and D4 are larger (3 millisecond at 2,200 feet/second), the assumption of a straight line round path is more critical. On the other hand, this is more than compensated by the increased time of flight to screen 3.



Changing D1 will rotate "Y" screen plane about lower corner.

Changing H will rotate plane about the center.

Changing D2 will rotate plane about upper corner.

"X" plane is similar but with D3; D4; and W

Displacement instead of angles and trigonometry was used in order to provide this increased flexability.

FIGURE 6. "Y" PARAMETERS SETUP

SENSITIVITY

Sensitivity can affect system error as shown by the following example:

$\Delta D1 = 0"$, $\Delta D2 = 6"$, $\Delta H = 2"$, $\Delta EV = 1"@10"$

ALL @ 1000" Range.

$\Delta D3 = 5"$, $\Delta D4 = 4"$, $\Delta W = 3"$, $\Delta EH = 1"@16"$

EV = Extreme Vertical Spread EH = Extreme Horizontal Spread

YLT and YFT are microsecond times to Y = 0 inches and Y = 72 inches, the minimum and maximum Y coordinates. They are calculated for each round and are, therefore, a function of round velocity and parameters D1 and D2. A one microsecond error in the chronograph can be resolved into a 0.052 inch error in the "Y".

XLT and XFT are similar to the above, but over a 70.0 inch span instead of a 72.0 inch span. A 1 microsecond error in time from the first screen to the third screen can be resolved into a 0.047 inch error, the percentage being 3 times lower.

A three or four word (12 bit) variable size had no appreciable effect.

BALLISTIC SCREEN

(Oehler Research Model 55) Quantity: 16 with 4 per stack.

Ballistic screens can affect system accuracy. The generated pulse, per specification, is 12 volts for 2-8 milliseconds with a 0.1 microsecond rise time and 0.1 millisecond fall time. Pulses are generated by five light sensitive diodes observing a 60 watt lumiline. Sensitivity is controlled by a 25 turn potentiometer. The highest number of errors are produced by the ballistic screens. These errors are

easily detected by the program and result in deletion of the entire round. Some error causes are listed below:

1. Flash and other external lighting

2. Blast

3. Debris covering the plexiglass window

4. Dust accumulation on lumiline

5. Vibration through floor

6. Shock waves directly from rounds and weapon, and reflected from walls and floor.

7. Misalignment and vribration of sensor shading and aiming column.

The last plane of ballistic screens seems to be the most susceptable to failure, presumably caused by shock transfer.

COUNTER CHRONOGRAPH

The chronograph (E.C.I. Model 4604, quantity: 3) has a 1 megahertz time base crystal with a 10 nanosecond error from $-20^{o}F$ to $+130^{o}F$ after 30 minutes of warm-up time. Error from the chronograph is, therefore, considered only a factor of readout, i.e., $\pm$ 1 microsecond.

B. TOTAL SYSTEM ERROR

The total system error was established with the aid of a digitizing table having an absolute accuracy of measured distance equal to $\pm$ 2.5 parts in 10^4 (e.g., $\pm$ .00025 inch in 1 inch), and paper targets with colored round signatures collected directly behind the velocity screens. The accuracy of this table output was, therefore, considered only a function of its follower's position.

For comparison, round displacement for both programs was taken from the second round. For a 20 round burst the average "X" error was -0.95 inch to +0.38 inch at a range of 1,000 inches. The maximum variation for 20 rounds was +1.14 to =0.87 calibers for "X" and +.32 to -1.11 calibers for "Y".

The system error (for 20 rounds with 50% probability) can be designated within $\pm$ 1/2 inch from actual position at 1,000 inches. This equates to 10 microseconds timing error.

See Appendix B for sample output.

APPENDIX A

COMPUTER PROGRAMS

The following program calculates the velocity, dispersion, and accuracy from the respective three times for each round. Other functions may be performed on command as noted in the command node group 23. The language is Digital Equipment Corporation's FOCAL.

Reference is given to Digital Equipment Corporation's "FOCAL-8 Programming Manual", No. DEC-08-AJAD-D, dated Januarv 1970.

```
@@@@@@@@@@
*C-8K FOCAL @1969
*
*01.01 C **V 18** AUTOMATIC TARGETING DEVICE PROGRAM
*01.02 T !!!!!!!! ;D 1.09;D 1.10;D 1.04;D 1.07;D 1.03;D 1.08;G 1.13
*01.03 T "AMMO LOT NUMBER              :LC-13-003",!
*01.04 T "GUN & S/N                    :XM230, 14",!
*01.07 T "VERTICAL RESTRAINT           :NO",!
*01.08 T "AMM0 & CAL.                  :XM639B1, 30MM",!
*01.09 A "TEST NUMBER                  :",%5,K1
*01.10 A "SPRING RATE & DAMPING        :",K2,K3
*01.13 S P1=0.0;S P2=0.0
*01.14 S DM=25*12 ;S D5=129.5;S II=0
*01.15 S H=71.00;S D1=15.00;S D2=49.00
*01.16 S W=73.00;S D3=74.00;S D4=110.5
*01.17 T "DATE  : 21JUNE76",!
*01.20 S N9=60
*01.30 S N=FN(-N9)
*01.31 I (N)1.3,1.3;I (N9-N) 1.38,1.4,1.32
*01.32 S NN=N;F I=1,N;S N(I)=I
*01.33 I (DM)1.34,1.36,1.34
*01.34 T "NO. RDS.= ",%3,N,!
*01.35 S Z=0;G 17.02
*01.36 D 1.13;D 1.14,D 1.15;D 1.16;G 1.34
*01.38 T "CORE OVERFLOW",!;S N=60;G 1.32
*01.40 T "CORE FILLED",!;G 1.32
*
*02.01 T "***ACCURACY*** TEST  ",%4,K1,!
*02.02 A "POINT OF AIM X&Y (IN.)  ",%6.02,PW,PF
*02.03 S P1=PW-53.0;S P2=98.5-PF
*02.05 S AX=0;S AY=0;D 2.11;D 2.12;G 2.15
*02.10 T "*** DESPERSION***  TEST  ",%6,K1,!
*02.11 S AR=0;S E=0;S G=0;S O=0;S MS=0;S R=0
*02.12 S MX=9999;S MY=9999;S LX=-9999;S LY=-9999
*02.13 S P1=0;S P2=0
*02.14 D 11
*02.15 F I=1,N;D 12;D 3;D 4;D 5;D 6;D 7;D 8
*02.50 T !, "EXTREME VERTICAL  ",%8.02,(LY-MY),"  MILLS",!
*02.60 T "EXTREME HORIZONTAL",%8.02,(LX-MX),"  MILLS",!
*02.70 T "MEAN RADIUS          ",%8.02,AR,"  MILLS",!
*02.72 T "STANDARD DEVIATION  X",%5.02,FSQT(E/(N-1)),"  MILLS",!
*02.74 T "STANDARD DEVIATION  Y",%5.02,FSQT(G/(N-1)),"  MILLS",!
*02.76 S R=0;S O=0;F I=1,N;D 12;D 7.10;D 10.05
*02.78 T "STANDARD DEVIATION R*"%5.02,FSQT(O/(N-1)),"  MILLS",!
*02.90 T "FIGURE OF MERIT   ",%8.02,(LX+LY-MX-MY)/2,!
*02.91 T "NUMBER OF ROUNDS     ",%5,N,!
*02.92 T !!!;G 23.01
*
*03.10 I (LX-X) 3.2;R
*03.20 S LX=X;S Y1=Y;R
*
*04.10 I (LY-Y) 4.2;R
*04.20 S LY=Y;S X1=X;R
*
*05.10 I (X-MX) 5.2;R
*05.20 S MX=X;S Y2=Y;R
*
*06.10 I (Y-MY) 6.2;R
*06.20 S MY=Y;S X2=X;R
*
*07.10 S R=FSQT((X-AX)↑2+(AY-Y)↑2)
*07.20 S AR=AR+R/N
*
*08.10 S E=E+(AX-X)↑2
*08.20 S G=G+(AY-Y)↑2
```

```
*10.Ø5 S O=O+R↑2
*
*11.5Ø C***CALCULATE X-Y COORDINATES***
*11.52 S SV=Ø;S A=Ø;S B=Ø
*11.56 F I=1,N;D 12
*11.57 S AX=A/N;S AY=B/N
*11.58 R
*
*12.1Ø S T1=FT((N(I)),1)/1ØØØØØØ;S T2=FT((N(I)),2)/1ØØØØØØ
*12.11 S T3=FT((N(I)),3)/1ØØØØØØ;IF (T3) 12.12,15.Ø1,12.12
*12.12 S V=D5/T3
*12.14 S YF=D1/V;S YL=D2/V
*12.16 S Y=-((H*(T1-YF)/(YL-YF))-P2);S B=B+Y
*12.18 S XF=D3/V;S XL=D4/V
*12.2Ø S X=(W*(T2-XF)/(XL-XF))-P1;S A=A+X
*
*13.1Ø S NB=N
*13.12 S I=Ø;S NB=NB-1
*13.14 I (NB-2) 28.11,13.16,13.16
*13.16 S I=I+1
*13.17 D 12;S Y1=FABS(Y);S I=I+1;D 12;S Y2=FABS(Y);S I=I-1
*13.18 I (Y1-Y2)13.22,13.22,13.2
*13.2Ø S CO=N(I);S N(I)=N(I+1);S N(I+1)=CO
*13.22 I (I-NB)13.16,13.12,13.12
*
*15.Ø1 T "T3=Ø",!
*15.1Ø T "***CHRONOGRAPH TIMES*** TEST  ",%5,K1,!
*15.2Ø T "TEST NO.        T(1)        T(2)        T(3)",!
*15.22 S I=1;I (N-1)15.3,15.4,15.3
*15.3Ø F I=1,N-1;D 15.4
*15.4Ø T %3,(N(I)),"      ",%1Ø,FT((N(I)),1),FT((N(I)),2),FT((N(I)),3),!
*15.6Ø T !!!;G 23.Ø1
*
*17.Ø2 F I=1,N;D 12.1;D 12.11;D 12.12;D 12.14;D 12.18;D 17.Ø4
*17.Ø3 S II=Ø;G 23.Ø1
*17.Ø4 I (YL-T1)18.7,18.7;I (XL-T2)18.7,18.7,17.Ø6
*17.Ø6 I (T1-YF)18.7,18.7;I (T2-XF)18.7,18.7,17.Ø8
*17.Ø8 S II=II+1;S N(II)=N(I)
*
*18.7Ø S N=N-1;I (N) 18.8,18.8
*18.8Ø T "ALL RDS. DELETED",!;S AZ=1Ø1;G 23.Ø1
*
*2Ø.Ø2 S I=N2;D 12;G 21.3
*2Ø.Ø3 S N2=1;S N3=N;G 2Ø.1
*2Ø.Ø6 A N2,N3;S L=-1
*2Ø.Ø7 I (N-N3)2Ø.Ø3,2Ø.Ø8,2Ø.Ø8
*2Ø.Ø8 I (N2)2Ø.Ø3,2Ø.Ø3,2Ø.Ø9
*2Ø.Ø9 I (N3-N2)2Ø.Ø3,2Ø.Ø2,2Ø.2
*2Ø.1Ø T "***X-Y COORDINATES *** TEST  ",%5,K1,!;I (AX+AY)2Ø.11,2Ø.15,2Ø.11
*2Ø.11 I (P1-AX)2Ø.15,2Ø.12,2Ø.15
*2Ø.12 I (P2+AY)2Ø.15,2Ø.13,2Ø.15
*2Ø.13 T "***CENTER OF IMPACT***",!
*2Ø.15 T "   RD. NO.      X              Y",!
*2Ø.17 S I=1;I (N3-1)2Ø.2,21.3,2Ø.2
*2Ø.2Ø F I=N2,N3;D 12;D 21.3Ø
*2Ø.4Ø T "",!!!!!!;S L=Ø;G 23.Ø1
*
*21.3Ø T "   ",%3,N(I),"      ",%5.Ø2,X,"      ",Y; I (L) 21.4;T !
*21.4Ø T %1Ø,FT((N(I)),1),FT((N(I)),2),FT((N(I)),3),!
*21.5Ø S L=Ø;T !;G 23.Ø1
*
```

```
*23.01 C***COMMAND NODE***
*23.02 S Z=Z+1;I (AZ-101)23.03,23.05
*23.03 S A(1)=ØV;S A(2)=Ø101;S P1=AX;S P2=-AY;S A(3)=ØPXY;S A(4)=ØQ
*23.04 S AA=A(Z);G 23.12
*23.05 T "#";A AA
*23.12 I (AA-ØRT)23.13,24.01
*23.13 I (AA-ØRR)23.14,24.01
*23.14 I (AA-ØPT) 23.16,15.1
*23.16 I (AA-ØV)23.18,24.11
*23.18 I (AA-ØPXY)23.19,20.03
*23.19 I (AA-ØL)23.2,20.06
*23.20 I (AA-Ø101)23.21,2.1
*23.21 I (AA-ØS) 23.22,28.01
*23.22 I (AA-ØPV)23.23,24.2
*23.23 I (AA-ØA)23.24,2.01
*23.24 I (AA-ØQ)23.25,24.1
*23.25 I (AA-ØDT)23.26,26.05
*23.26 T "PT-------PRINT CHRONOGRAPH TIMES",!
*23.30 T "PXY------PRINT X-Y COORDINATES",!
*23.31 T "L N2,N3--LIST RDS. N2 TO N3",!
*23.32 T "101------RUN PROG. 101 DESPERSION",!
*23.33 T "V--------PRINT AVERAGE VELOCITY",!
*23.34 T "PV-------PRINT ALL VELOCITIES",!
*23.35 T "DT N1----DELETE TEST NO.",!
*23.36 T "RR-------RESTORE ALL ROUNDS",!
*23.38 T "A--------CALCULATE ACCURACY",!
*23.39 T "RT-------RESTORE ALL TESTS",!
*23.40 T "S--------PLOT ALL SELECTED POINTS",!
*23.98 T "Q--------QUIT",!
*23.99 G 23.01
*
*24.01 C***RESTORE ALL DELETED RDS.***
*24.03 F I=1,NN;S N(I)=I
*24.05 S N=NN;G 23.01
*24.10 QUIT
*24.11 S SV=Ø;D 2.12
*24.12 F I=1,N;D 25.1;D 25.11;D 25.13
*24.14 D 24.8;D 24.81;D 24.82;G 24.85
*24.20 T "***PRINT ALL VELOCITIES*** TEST  ",%5,K1,!
*24.30 D 2.12
*24.40 T "RD. NO.         VELOCITY (FT./SEC.)",!
*24.50 S SV=Ø
*24.60 F I=1,N;D 25
*24.80 T !, "AVERAGE VELOCITY ",%8.02,SV/N," FOR ",%3,N," RDS.",!
*24.81 T "HIGHEST VEL.",%8.02,LX,!
*24.82 T "LOWEST VEL. ",%8.02,MX,!
*24.85 T !!!;G 23.01
*
*25.10 S T3=FT((N(I)),3)/1000000;S V=(D5/T3)/12
*25.11 S SV=SV+V
*25.12 T %3,I,"      ",%8.02,V,!
*25.13 S X=V;D 3;D 5
*25.14 R
*
*26.05 C***DELETE ROUND***
*26.10 A %3,N1
*26.16 F I=1,N;D 27
*26.18 G 23.01
*
*27.05 I (N(I)-N1)27.4,27.1,27.1
*27.10 I (I-N)27.16,27.2,27.16
*27.16 S N(I)=N(I+1);R
*27.20 S N=N-1;R
*27.40 R
*
```

```
*28.01 S P1=0;S P2=0
*28.02 T !!,"TEST NO. ",%3,K1,!!!,"  "
*28.03 T "000000000011111111112222222222333333333344444444445555555555"
*28.04 T !,"   ";F L=1,6;T "0123456789"
*28.08 T !
*28.10 G 13.1
*28.11 C***PLOT X-Y***
*28.12 S I=1;D 12;T !,%2,FITR(FABS(Y)),#;S X2=X;D 28.3;D 28.4
*28.15 F I=2,N;D 28.18;D 28.19;D 28.3;D 28.4;
*28.17 T !!!;G 23.01
*28.18 S I=I-1;D 12;S Y1=FABS(Y);S I=I+1;D 12;S Y2=FABS(Y);S X2=X
*28.19 I (FITR(Y1)-FITR(Y2))28.2,28.25,28.2
*28.20 F J=FITR(Y1)+1,FITR(Y2);T !,%2,J,#
*28.25 T #
*28.30 F K=-1,FITR(X2);T " "
*28.40 T "+"
**@@@@@@@@@@@@@@@@@@@@@
```

The following subroutines are written in Digital Equipment Corporation's PAL III assembly language and are overlays to and interfaces with FOCAL.

Subroutine XFILL fills core in field 1 with chronograph BCD data.

Subroutine XFT retrieves this data, converts the BCD to FOCAL floating point variables and interfaces with FOCAL.

There are two sources of information which are helpful in setting up programs. They are: "Focal, How to Write New Subroutines and Use Internal Routines"[1], and overlays[2] from the Bedford Computer System, Inc. for the digitizing table.

[1]Doug Wrege, "Focal, How to Write New Subroutines and Use Internal Routines", Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia, circa 1970, 37 pp.

[2]Private communication from Bedford Computer System, Inc., 14616 Southland Lane, Rockville, Maryland 20850.

AARRAY	4571
ABLOCK	4676
ACONV1	4572
ACOUNT	4577
AGET	4573
ALIMIT	4570
APOINT	4557
ARG	4647
ARRAY	4631
ASTO	4574
AXX10	4567
BLOCK	4576
CONV	4515
CONV1	4600
COUNT	4645
COUNT1	4556
C0002	4563
C0013	4575
C0017	4616
DEL	4410
DELAY	4564
DELAY1	4565
DELAY2	4566
END	4421
FLPC	4610
GET	4660
LIMIT	4617
LLOP1	4405
LOOP	4415
MCOMMA	4657
MI01	4646
POINT	4675
PTABLE	4560
RD	4430
STO	4666
TEMP	4561
TEMP1	4562
TIME	4555
XFILL	4400
XF1	4456
XF2	4510
XF3	4512
XX1	4501
XX10	4613

```
EXPUNGE
FIXMRI  AND=0000
FIXMRI  TAD=1000
FIXMRI  ISZ=2000
FIXMRI  DCA=3000
FIXMRI  JMS=4000
FIXMRI  JMP=5000
FIXMRI  FADD=1000
FIXMRI  FDIV=3000
FIXMRI  FMUL=4000
FLAC=44
FEXT=0
FINT=JMS I  7
HLT=7402
CAF=6007
IOF=6002
SKP=7410
CMA=7040
CLL=7100
CLA=7200
IAC=7001
SZA=7440
SNA=7450
SMA=7500
RTL=7006
RTR=7012
TABLE=126
ERROR3=4566
ERROR2=4566
EFUN3I=136
BOTTEM=35
FNTABF=374
FNTABL=2165
INTEGER=53
BUFR=60
ENDT=135
START=4400
CHAR=66
PUSHJ=4540
EVAL=1613
POPJ=5541
FIXTAB
PAUSE
```

```
                *BOTTEM
0035    4377    START-1
                *BUFR
0060    0750    TABLE+688
                *ENDT
0135    0750    TABLE+688
                *FNTABF+14
0410    4400    XFILL
0411    4456    XFT
                *FNTABL+14
2201    0316    316         /FNLL ASCII "N"
2202    0324    324         /FT ASCII "T"
                *START
4400    4770    XFILL,      JMS I ALIMIT
4401    3356                DCA COUNT1
4402    1360                TAD PTABLE
4403    3757                DCA I APOINT
4404    7000                7000     /NOP
4405    7000    LLOP1,      7000                /NOP
4406    1364                TAD DELAY
4407    3365                DCA DELAY1
4410    2366    DEL,        ISZ DELAY2
4411    5215                JMP LOOP
4412    2365                ISZ DELAY1
4413    5210                JMP DEL
4414    5221                JMP END
4415    6153    LOOP,       6153
4416    7410                SKP
4417    5230                JMP RD
4420    5210                JMP DEL
4421    7200    END,        CLA
4422    1375                TAD C0013
4423    3044                DCA FLAC
4424    3046                DCA FLAC+2
4425    1356                TAD COUNT1
4426    3045                DCA FLAC+1
4427    5536                JMP I EFUN3I
4430    7200    RD,         CLA
4431    3366                DCA DELAY2
4432    6144                6144     /READ MSW
4433    4774                JMS I ASTO
4434    6154                6154     /READ LSW & RESET
4435    4774                JMS I ASTO
4436    6173                6173     /SKP IF FLAG SET
4437    5236                JMP .-1  /NO THEN LOOP
4440    6164                6164     /YES READ MSW
```

```
4441   4774           JMS I ASTO
4442   6174           6174     /READ LSW
4443   4774           JMS I ASTO
4444   6323           6323     /FLAG 32 SET?
4445   5244           JMP .-1 /NO: LOOP
4446   6314           6314     /YES: READ MSW
4447   4774           JMS I ASTO
4450   6324           6324     /READ LSW & RESET
4451   4774           JMS I ASTO
4452   2356           ISZ COUNT1
4453   2777           ISZ I ACOUNT
4454   5205           JMP LLOP1
4455   5221           JMP END
4456   477Ø   XFT,    JMS I ALIMIT
4457   4771           JMS I AARRAY
446Ø   454Ø           PUSHJ
4461   4647           ARG
4462   74Ø2           HLT      /ERROR
4463   4453           JMS I INTEGER
4464   7Ø41           CMA IAC /NEG IN AC
4465   3355           DCA TIME
4466   1376           TAD BLOCK
4467   2355           ISZ TIME
447Ø   741Ø           SKP
4471   53Ø1           JMP XX1
4472   2355           ISZ TIME
4473   741Ø           SKP
4474   531Ø           JMP XF2
4475   2355           ISZ TIME
4476   741Ø           SKP
4477   5312           JMP XF3
45ØØ   74Ø2           HLT      /ERROR
45Ø1   136Ø   XX1,    TAD PTABLE
45Ø2   3757           DCA I APOINT
45Ø3   4773           JMS I AGET
45Ø4   3361           DCA TEMP        /MSW
45Ø5   4773           JMS I AGET
45Ø6   3362           DCA TEMP1       /LSW
45Ø7   5315           JMP CONV
451Ø   1363   XF2,    TAD CØØØ2
4511   53Ø1           JMP XX1
4512   1363   XF3,    TAD CØØØ2
4513   1363           TAD CØØØ2
4514   53Ø1           JMP XX1
```

```
4515  7300  CONV,    CLA CLL
4516  3044           DCA FLAC
4517  3045           DCA FLAC+1
4520  3046           DCA FLAC+2
4521  1361           TAD TEMP
4522  7112           RTR CLL
4523  7012           RTR
4524  7012           RTR
4525  7012           RTR
4526  4772           JMS I ACONV1
4527  1361           TAD TEMP
4530  7112           RTR CLL
4531  7012           RTR        /MS BCD
4532  4772           JMS I ACONV1
4533  1361           TAD TEMP
4534  4772           JMS I ACONV1
4535  1362           TAD TEMP1
4536  7112           RTR CLL
4537  7012           RTR
4540  7012           RTR
4541  7012           RTR
4542  4772           JMS I ACONV1
4543  1362           TAD TEMP1
4544  7112           RTR CLL
4545  7012           RTR
4546  4772           JMS I ACONV1
4547  1362           TAD TEMP1          /LS BCD
4550  4772           JMS I ACONV1
4551  4407           FINT
4552  3767           FDIV I AXX10
4553  0000           FEXT
4554  5536           JMP I EFUN3I
4555  0000  TIME,    0
4556  0000  COUNT1,  0
4557  4675  APOINT,  4675
4560  0126  PTABLE,  TABLE
4561  0000  TEMP,    0
4562  0000  TEMP1,   0
4563  0002  C0002,   2
4564  7700  DELAY,   7700
4565  0000  DELAY1,  0
4566  0000  DELAY2,  0
4567  4613  AXX10,   4613
4570  4617  LIMIT,   4617
4571  4631  AARRAY,  4631
4572  4600  ACONV1,  4600
4573  4660  AGET,    4660
4574  4666  ASTO,    4666
4575  0013  C0013,   0013
4576  0000  BLOCK,   0000
4577  4645  ACOUNT,  4645
```

```
                *4600
4600    0000    CONV1,  0
4601    0216            AND C0017       /MASK & GET BCD
4602    3211            DCA FLPC+1
4603    4407            FINT
4604    1210            FADD FLPC       /CONVERT FROM BCD
4605    4213            FMUL XX10       / TO    FLOATING PT.
4606    0000            FEXT
4607    5600            JMP I CONV1
4610    0013    FLPC,   13
4611    0000            0
4612    0000            0
4613    0004    XX10,   4
4614    2400            2400
4615    0000            0
4616    0017    C0017,  0017
4617    0000    LIMIT,  0
4620    4453            JMS I INTEGER
4621    3245            DCA COUNT
4622    1245            TAD COUNT
4623    7450            SNA
4624    7402            HLT     /ERROR
4625    1246            TAD M101
4626    7700            SMA CLA
4627    7402            HLT     /ERROR
4630    5617            JMP I LIMIT
4631    0000    ARRAY,  0
4632    7040            CMA
4633    1245            TAD COUNT       /SUBTRACT 1 FROM COUNT
4634    3245            DCA COUNT
4635    1245            TAD COUNT
4636    1245            TAD COUNT
4637    1245            TAD COUNT
4640    1245            TAD COUNT
4641    1245            TAD COUNT
4642    1245            TAD COUNT       /MUL COUNT BY 6
4643    3676            DCA I ABLOCK
4644    5631            JMP I ARRAY     /BLOCK CONTAINS APP. BLOCK
4645    0000    COUNT,  0
4646    7633    M101,   -145


4647    1066    ARG,    TAD CHAR
4650    1257            TAD MCOMMA
4651    7640            SZA CLA /A COMMA?
4652    5256            JMP .+4 /YES: EXIT VIA POPJ
4653    4540            PUSHJ
4654    1612            EVAL-1
4655    7001            IAC
4656    5541            POPJ
4657    7524    MCOMMA, 7524
4660    0000    GET,    0
4661    6211            6211
```

```
4662  1675            TAD I POINT
4663  6201            6201
4664  2275            ISZ POINT
4665  5660            JMP I GET
4666  0000  STO,      0
4667  6211            6211
4670  7040            CMA      /COMP. OF BCD RECIEVER
4671  3675            DCA I POINT
4672  6201            6201
4673  2275            ISZ POINT
4674  5666            JMP I STO
4675  0000  POINT,    000
4676  4576  ABLOCK,   4576

AARRAY   4571
ABLOCK   4676
ACONV1   4572
ACOUNT   4577
AGET     4573
ALIMIT   4570
APOINT   4557
ARG      4647
ARRAY    4631
ASTO     4574
AXX10    4567
BLOCK    4576
CONV     4515
CONV1    4600
COUNT    4645
COUNT1   4556
C0002    4563
C0013    4575
C0017    4616
DEL      4410
DELAY    4564
DELAY1   4565
DELAY2   4566
END      4421
FLPC     4610
GET      4660
LIMIT    4617
LLOP1    4405
LOOP     4415
MCOMMA   4557
M101     4646
POINT    4675
PTABLE   4560
RD       4430
STO      4666
TEMP     4561
TEMP1    4562
TIME     4555
X
```

The following external ballistic program is written in FOCAL and used to establish the effective muzzle velocity given the ballistic screen velocity and location downrange. Other input requirements are documented in the program. This program provides engineering approximations and can be used for any caliber and configuration projectile.

Due to core requirements of the PDP 8, program accuracy is limited; however, this accuracy is well within test requirements.

The program was originated at Rodman Laboratory, Rock Island Arsenal by Dennis D. Ladd.

W A

C-8K FOCAL @1976

```
01.01 T !!!!!!!!, "***EXTERNAL BALLISTICS PROGRAM***V5",!
01.02 C   THIS PROGRAM USES COL. MAYEVSKI'S BRACKET FUCTION
01.04 C OBTAINED FROM FIRINGS DONE BY KRUPP AT MEPPEN GERMANY
01.06 C (1881) USEING A PROJECTILE 3 CAL. LONG ; 2 CAL. OGIVAL
01.08 C HEAD RADIUS ; WEIGHT 1 LB. ; DIA. 1 IN..  THIS SAME PROJECTILE
01.10 C WAS FIRED BY THE GAVRE COMMISSION (1918) RESULTING IN THEIR
01.12 C G-FUCTION .  ONLY SLIGHT MODIFICATIONS WERE MADE FOR A.P.G.'S
01.14 C G1-FUCTION.
01.16 C   THE FORM FACTOR (I) CORRECT DIFFERENCES BETWEEN THE ABOVE
01.18 C STANDARD PROJECTILE AND THE PROJECTILE BEING EVALUATED.
01.20 C THIS FACTOR MAY BE OBTAINED FROM THE REF. NOTED BELOW.
01.22 E

02.01 A "PROJECTILE WEIGHT (GRAINS) ?  ",%,W0
02.02 S W=W0/7000
02.04 A "PROJECTILE DIAMETER (MM) ?  ",%,D0
02.06 S D=D0*.03937
02.08 A "AIR DENSITY RAITO ?  ",%,DR
02.10 C REF. HATCHER'S NOTEBOOK P.574 & 430
02.12 A "FORM FACTOR ?  ",%,I
02.14 C REF. HATCHER'S NOTES P.571 & 572 OR "SHORT CUT TO BALLISTICS"
02.16 S C=DR*W/(I*D↑2)

03.01 A "VELOCITY (FT/SEC) & RESPECTIVE RANGE (IN,) ??  ",%,VX,XX
03.02 S XX=XX/12
03.03 A "MAXIMUM RANGE (M) ?  ",%,XE
03.04 S XE=XE*3.280833
03.06 A "RANGE INCREMENT (M) ?  ",%,XI
03.07 C INCREMENT IS CRITICAL TO ACCURACY !!
03.08 S XI=XI*3.280833
03.10 A "ANGLE OF ELEVATION (DEGREES) ?  ",%,TH;S TH=TH*3.1416/180

04.01 S V=VX;D 10
04.02 S AX=R/C
04.04 S V0=FSQT(VX↑2+2*AX*XX)
04.06 S V=V0;D 10
04.08 S AF=R/C;S AX=(AF+AX)/2;D 4.04
```

```
05.01 T !!!
05.02 T "PROJECTILE WEIGHT        :",%5.04,W," LBS.",!
05.04 T "PROJECTILE DIAMETER      :",%5.04,D," INCHES",!
05.06 T "FORM FACTOR              :",%5.04,I,!
05.08 T "AIR DENSITY RAITO        :",%5.04,DR,!
05.10 T "BALLISTIC COEFFICIENT :",%5.04,C,!
05.11 T "MUZZLE VELOCITY          :",%5.02,V0," FT/SEC",!!
05.14 T "                         REMAINING          TOTAL          TRAJECTORY"!
05.16 T " RANGE    TIME           HORZ. VEL.         VELOCITY          DROP ",!
05.18 T "  (M)     (SEC)          (FT/SEC)           (FT/SEC)          (FT) ",!!

06.01 S V1=V0*FCOS(TH);S V3=V1
06.02 S V2=V0*FSIN(TH);S V4=V2
06.04 S X=0;S Y=0;S T=0
06.06 D 7.18;D 7.20
06.08 F X=XI,XI,XE;D 7
06.10 QUIT

07.02 S V=V3;D 10;S A0=R/C
07.04 S V5=FSQT(V3↑2-2*A0*XI)
07.06 S T1=2*XI/(V3+V5)
07.08 S V3=V5
07.10 S V6=V4-32.16*T1
07.12 S T=T+T1
07.14 S Y=Y+T1*(V4+V6)/2
07.16 S V4=V6
07.18 T %5.00,X/3.280833,%8.05,T,%8.01,V3,%15.01,FSQT(V3↑2+V4↑2)
07.20 T "            ",%8.04,Y,!

10.01 C MAYEVSKI RETARDATION FUCTION (R=A*V↑M) FT/SEC↑2
10.02 I (840-V)10.04
10.03 S S5=V↑38;D 11.02;S R=7.442E-04*V*S6;R
10.04 I (1040-V)10.08
10.06 S R=5.9939E-08*V↑3;R
10.08 I (1190-V)10.12
10.10 S S5=V↑29;D 11.02;S R=2.3385E-18*V↑6*S6;R
10.12 I (1460-V)10.16
10.14 S R=9.5408E-08*V↑3
10.16 I (2000-V)10.20
10.18 S S5=V↑51;D 11.02;S R=5.9814E-04*V*S6;R
10.20 I (2600-V)10.24
10.22 S R=5.8495E-03*V*FSQT(V);R
10.24 I (4000-V)10.28
10.26 S S5=V↑43;D 11.02;S R=1.5366E-03*V*S6;R
10.28 T "VELOCITY OUT OF RANGE",!
10.30 QUIT

11.01 C S6= 64 TH ROOT OF S5
11.02 S S6=FSQT(FSQT(FSQT(FSQT(FSQT(FSQT(S5))))))
*
```

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APPENDIX B

SYSTEM ACCURACY

The following ASR output is from the paper target (Figure B-1) using the digitizing table. These X and Y coordinates, as explained earlier, are to be considered actual within $\pm$ .05 inches. The statistics are also considered accurate and can be compared to the ATD output.

TEST NO. & DATE: 454, 2JUN76
WEAPON & S/N: [redacted]
VERTICAL SUPPORT YES
SPRING RATE & DAMPIMG: 65K, .3
30 MM XM639B1 AMMO LOT: LC-13-002
NUMBER OF ROUNDS: 20

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

EXTREME VERTICAL		9.61	MILLS
EXTREME HORIZONTAL		10.85	MILLS
EXTREME SPREAD		11.86	MILLS
MEAN RADIUS		2.49	MILLS
STANDARD DEVIATION	X	2.59	MILLS
STANDARD DEVIATION	Y	1.80	MILLS
STANDARD DEVIATION	R	1.85	MILLS

CENTER OF IMPACT:

X		0.62	MILLS	FROM RD # 2
Y	-	5.67	MILLS	

*** X-Y COORDINATES ***

RD NO		X		Y
1		6.94	-	9.62
2		0.00	-	0.00
3	-	3.90	-	5.18
4	-	3.81	-	7.56
5	-	2.79	-	4.52
6	-	0.86	-	5.59
7		3.22	-	5.85
8		3.05	-	4.57
9	-	0.25	-	5.28
10		1.51	-	6.40
11		0.00	-	5.46
12	-	1.37	-	5.92
13	-	0.21	-	5.88
14		0.22	-	4.97
15		1.81	-	5.94
16		3.23	-	6.75
17		1.09	-	4.50
18		0.04	-	7.27
19		2.10	-	6.69
20		2.31	-	5.50

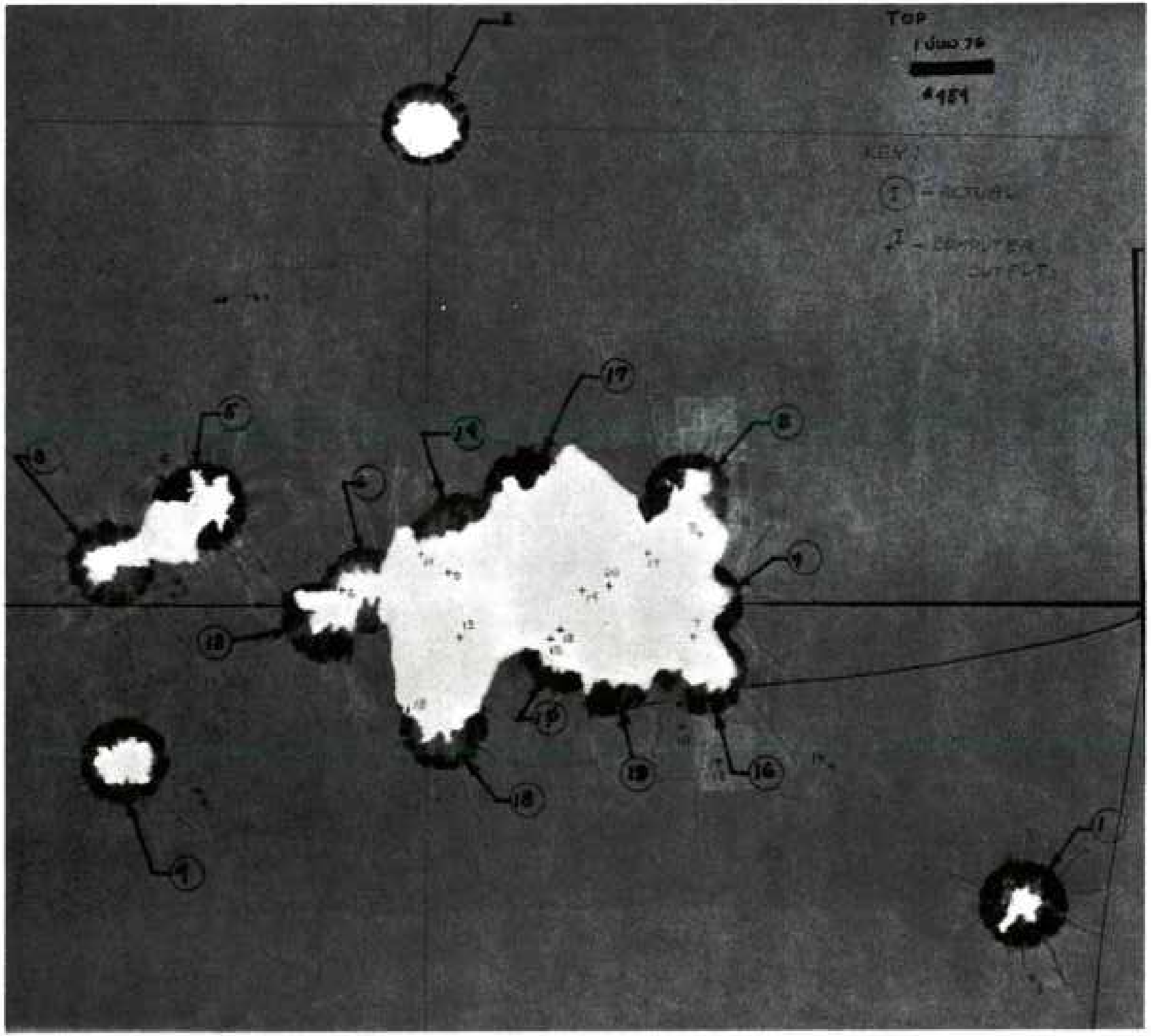


FIGURE B-1. COLOR CODED PAPER TARGET

TEST NO. & DATE: 454, 2JUN76
WEAPON & S/N: [redacted]
VERTICAL SUPPORT YES
SPRING RATE & DAMPING: 65K, .3
30 MM XM639B1 AMMO LOT: LC-13-002
NUMBER OF ROUNDS: 20

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

EXTREME VERTICAL		9.61	MILLS
EXTREME HORIZONTAL		10.85	MILLS
EXTREME SPREAD		11.86	MILLS
MEAN RADIUS		2.49	MILLS
STANDARD DEVIATION	X	2.59	MILLS
STANDARD DEVIATION	Y	1.80	MILLS
STANDARD DEVIATION	R	1.85	MILLS

CENTER OF IMPACT:

X	0.62	MILLS	From RD # 2
Y	- 5.67	MILLS	

*** X-Y COORDINATES ***

RD NO	X	Y
1	6.94	- 9.62
2	0.00	- 0.00
3	- 3.90	- 5.18
4	- 3.81	- 7.56
5	- 2.79	- 4.52
6	- 0.86	- 5.59
7	3.22	- 5.85
8	3.05	- 4.57
9	- 0.25	- 5.23
10	1.51	- 6.40
11	0.00	- 5.46
12	- 1.37	- 5.92
13	- 0.21	- 5.88
14	0.22	- 4.97
15	1.31	- 5.94
16	3.23	- 6.75
17	1.09	- 4.59
18	0.04	- 7.27
19	2.10	- 6.69
20	2.31	- 5.50

```
#PXY
***X-Y COORDINATES *** TEST      454
   RD.  NO.         X              Y
    2         -   0.00      -    0.00
    5         -   3.29      -    4.33
    8             3.46      -    4.90
   11         -   0.05      -    5.15
   17             2.73      -    5.17
    9             0.21      -    5.37
    6         -   1.17      -    5.50
   20             2.24      -    5.52
    3         -   2.98      -    5.58
   14             1.89      -    5.63
   12         -   1.69      -    5.96
   13             0.42      -    6.11
    7             3.44      -    6.23
   15             1.57      -    6.32
   10             3.16      -    7.16
   18         -   0.15      -    7.44
   19             3.57      -    7.67
   16             5.14      -    7.79
    4         -   2.74      -    8.17
    1             7.47      -   10.13
```

```
#RR
#PXY
***X-Y COORDINATES *** TEST      454
   RD.  NO.         X              Y
    1             7.47      -   10.13
    2         -   0.00      -    0.00
    3         -   2.98      -    5.58
    4         -   2.74      -    8.17
    5         -   3.29      -    4.33
    6         -   1.17      -    5.50
    7             3.44      -    6.23
    8             3.46      -    4.90
    9             0.21      -    5.37
   10             3.16      -    7.16
   11         -   0.05      -    5.15
   12         -   1.69      -    5.96
   13             0.42      -    6.11
   14             1.89      -    5.63
   15             1.57      -    6.32
   16             5.14      -    7.79
   17             2.73      -    5.17
   18         -   0.15      -    7.44
   19             3.57      -    7.67
   20             2.24      -    5.52
```

```
#PXY
***X-Y COORDINATES *** TEST      454
   RD.  NO.        X              Y
   5              34.68       -  5?00.00 @ 20.20
*S P1=37.97;S P2=48.26
*G 23.01
#PXY
***X-Y COORDINATES *** TEST      454
   RD.  NO.        X              Y
   5          -   3.29      -   4.33
   3          -   2.98      -   5.58
   4          -   2.74      -   8.17
  12          -   1.69      -   5.96
   6          -   1.17      -   5.50
  18          -   0.15      -   7.44
  11          -   0.05      -   5.15
   2          -   0.00      -   0.00
   9              0.21      -   5.37
  13              0.42      -   6.11
  15              1.57      -   6.32
  14              1.89      -   5.63
  20              2.24      -   5.52
  17              2.73      -   5.17
  10              3.16      -   7.16
   7              3.44      -   6.23
   8              3.46      -   4.90
  19              3.57      -   7.67
  16              5.14      -   7.79
   1              7.47      -  10.13
```

```
#S


TEST NO.   454


    000000000011111111112222222222333333333344444444445555555555
    012345678901234567890123456789012345678901234567890123456789

48                                       +
49
50
51
52                                    +
53                                    + ++++++
54                                      + ++ +
55                                       +   +
56                                     +       +
57
58                                               +

#O
```

```
*S AZ=1Ø1
*G 23.Ø1
#S


TEST NO.  454


  ØØØØØØØØØØ1111111111222222222233333333334444444444555555555
  Ø123456789Ø123456789Ø123456789Ø123456789Ø123456789Ø123456789

 48                                             +  2
 49
 5Ø
 51
 52                                          +  5
 53                                                 +  8
                                                +  11
                                                   +  17
                                                 +  9
                                               +  6
                                                   +  2Ø
                                            +  3
                                                  +  14
 54                                            +  12
                                                 +  13
                                                    +  7
                                                  +  15
 55                                                 +  1Ø
                                                +  18
                                                    +  19
 56                                                   +  16
                                              +  4
 57
 58                                                       +  1
```

AMMO & CAL. :XM639B1, 30MM
AMMO LOT NUMBER :LC-13-008
GUN & S/N [redacted]
VERTICAL RESTRAINT :YES
TEST NUMBER :454
SPRING RATE & DAMPING :65K, .3
DATE : 1JUNE76
NO. RDS.= 20

AVERAGE VELOCITY 2258.51 FOR 20 RDS.
HIGHEST VEL. 2285.40
LOWEST VEL. 2232.91

*** DESPERSION*** TEST 454

EXTREME VERTICAL		10.13	MILLS
EXTREME HORIZONTAL		10.76	MILLS
MEAN RADIUS		2.82	MILLS
STANDARD DEVIATION	X	2.83	MILLS
STANDARD DEVIATION	Y	1.97	MILLS
STANDARD DEVIATION	R	1.38	MILLS
FIGURE OF MERIT		10.44	
NUMBER OF ROUNDS		20	

***X-Y COORDINATES *** TEST 454
CENTER OF IMPACT

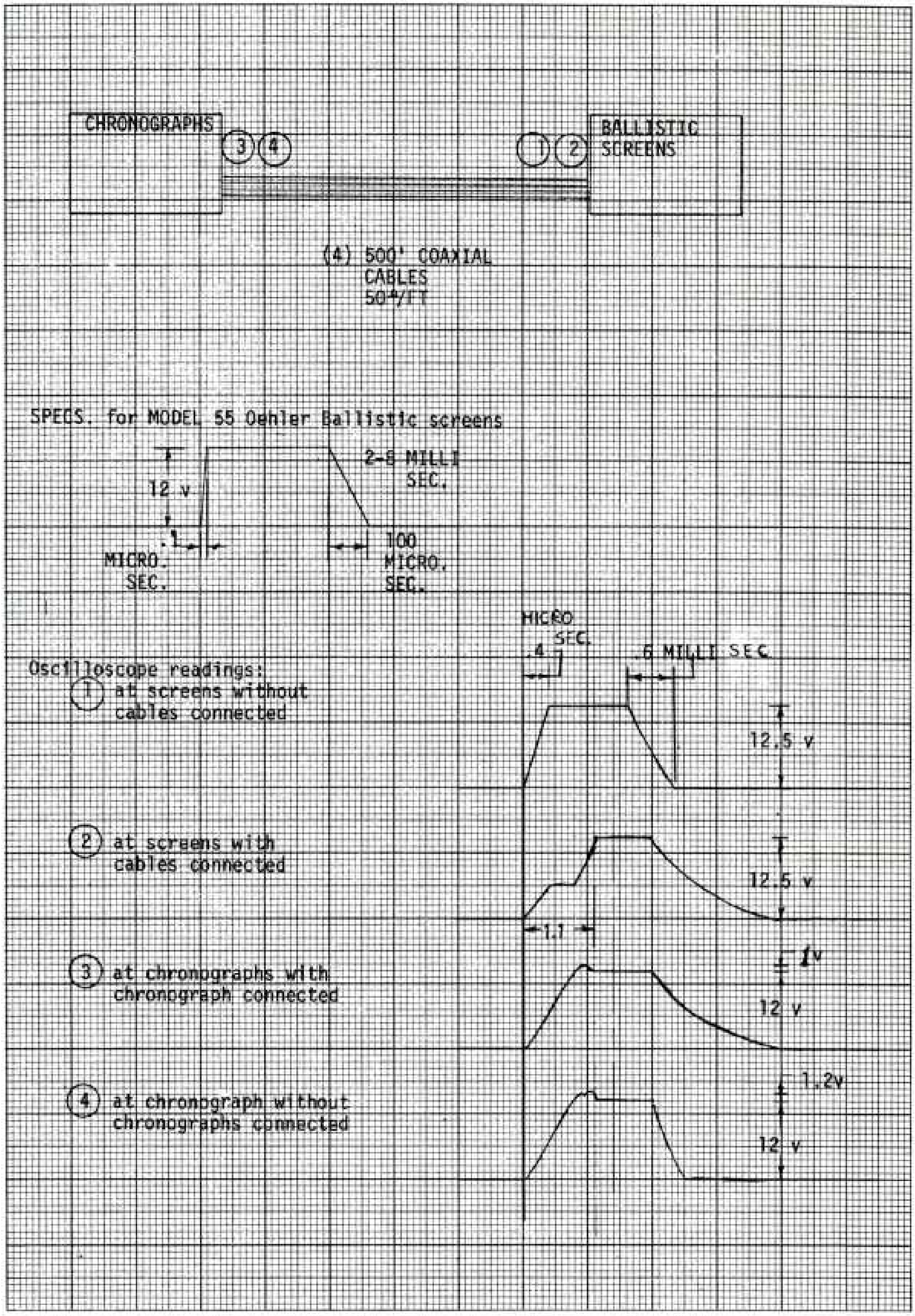
RD. NO.	X	Y
1	6.31	-4.12
2	-1.17	6.00
3	-4.14	0.42
4	-3.90	-2.17
5	-4.45	1.68
6	-2.33	0.50
7	2.27	-0.22
8	2.30	1.11
9	-0.95	0.64
10	2.00	-1.16
11	-1.21	0.86
12	-2.85	0.05
13	-0.74	-0.10
14	0.73	0.37
15	0.41	-0.32
16	3.98	-1.78
17	1.57	0.83
18	-1.31	-1.43
19	2.41	-1.66
20	1.08	0.48

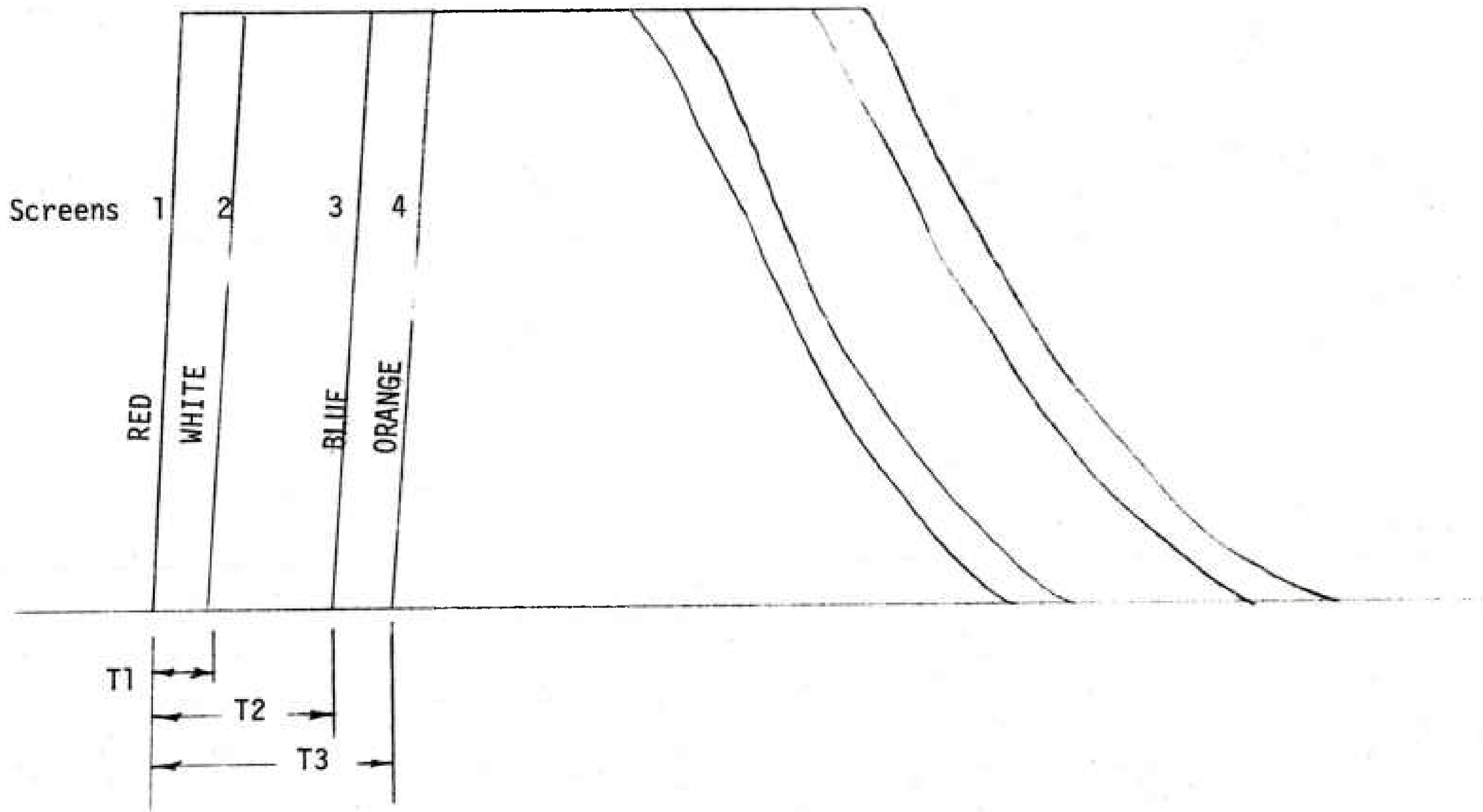
This page is intentionally left blank.

APPENDIX C

CHRONOGRAPH/BALLISTIC SCREEN INTERFACE

The interface pulses between the chronographs and the ballistic screens are relevant in observing proper operation of the system. Page C-3 shows the pulse shape for the test conditions (oscilloscope readings) 1, 2, 3, and 4. The effects of line capacitance and impedance mismatch can be seen in test 3 and 4. Page C-4 shows the pulse time relationship as obtained from a 4 channel storage tube oscilloscope for test condition 1. The positive active chronographs will then record times T1, T2, and T3. Page C-5 is a listing of the times T1, T2, and T3 in microseconds from the computer core. The actual number of rounds fired was 30. The 2nd, 3rd, 4th, 28th, and 30th test number would be deleted automatically by the computer for further calculations. The program will then obtain a renumbering for the rounds. The program can actually delete either the erroneous test number or round number on command. The distinction between erroneous test number and round number is obvious in this example due to the extra pulse received in test 2, because all three times are beyond reasonable limits. Once acceptable criteria for the distinction is made, the program could be improved to automatically perform this operation. Pages C-6 through C-8 are TEXTRONIX 4010 printouts of the respective screen plane pulses. The screen printouts can be compared directly to the listing on page C-5. Erroneous pulses shown on page C-8 are eliminated by the one-shot action of the chronographs. A 10 volt cut-off of the pulses is due to A/D saturation. The elimination of erroneous pulses from page C-8 to the print-out on page C-5 illustrates the effectiveness of the setup.


CHRONOGRAPHS
3
4
1
2
BALLISTIC SCREENS
(4) 500' COAXIAL CABLES 50¢/FT
SPECS. for MODEL 55 Oehler Ballistic screens
12 v
.1
MICRO. SEC.
MILLI SEC.
100 MICRO. SEC.
MICRO SEC.
.4
.6 MILLI SEC
Oscilloscope readings:
1 at screens without cables connected
12.5 v
2 at screens with cables connected
12.5 v
1.1
1v
3 at chronographs with chronograph connected
12 v
1.2v
4 at chronograph without chronographs connected
12 v

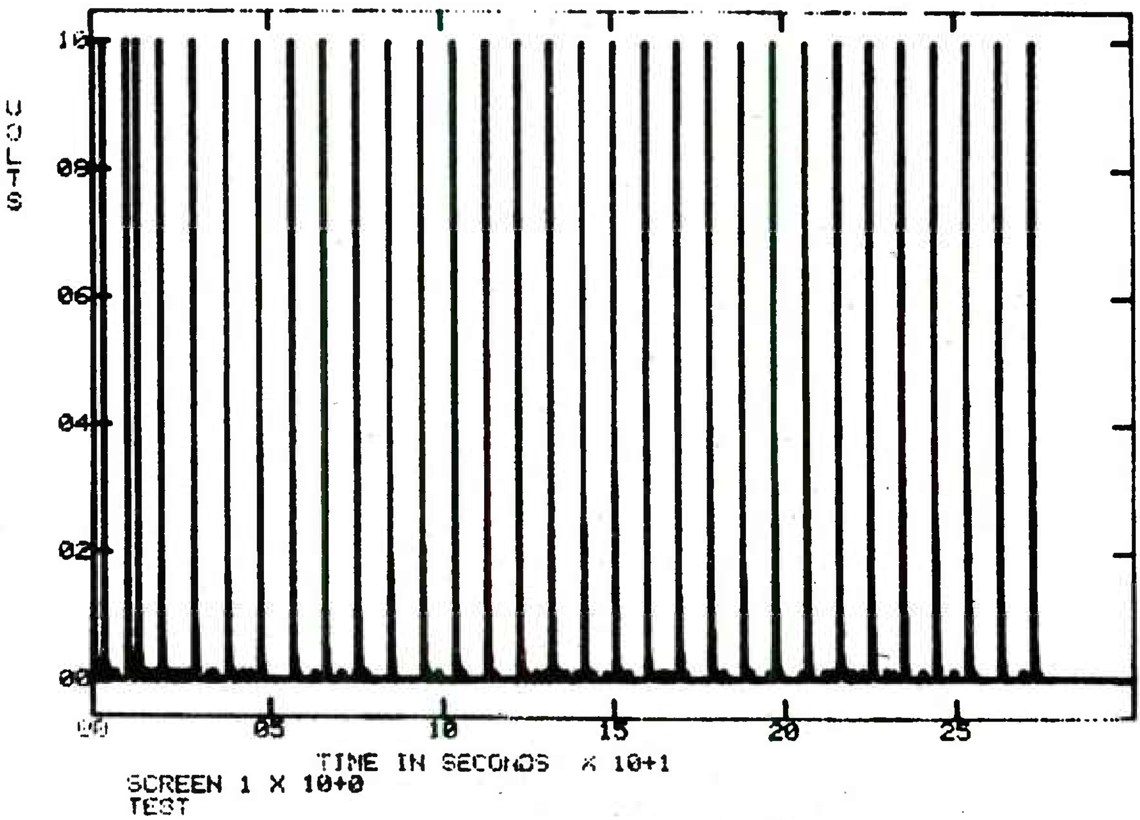


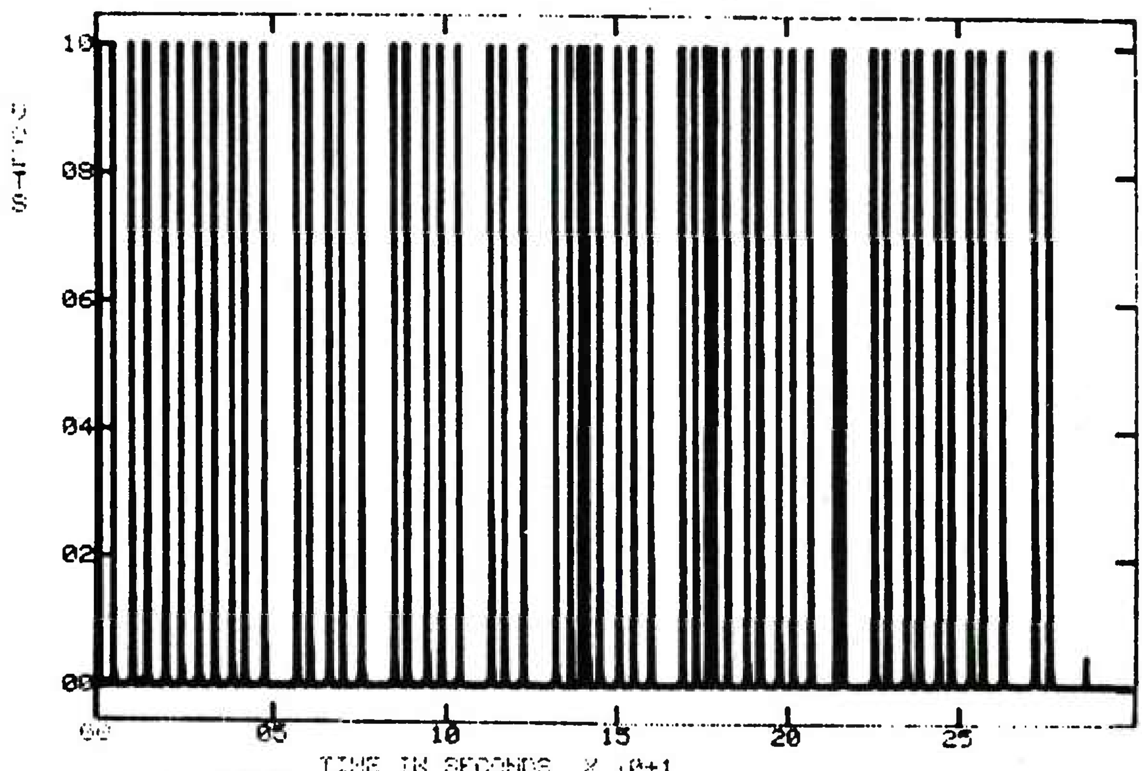
PULSE RELATIONSHIP (See Fig. 4 for Explanation)

Q
*G

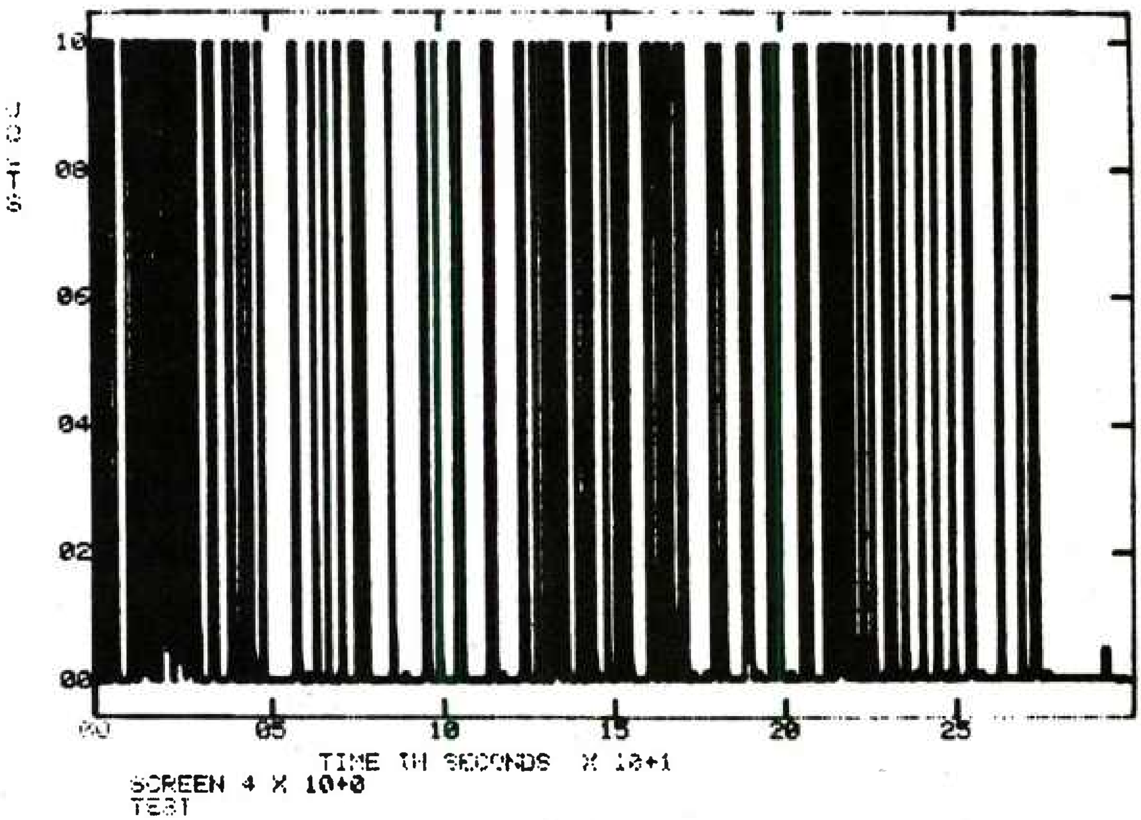
TEST NO. : [redacted]
NO. RDS.= 31
#PT
CHRONOGRAPH TIMES TEST [redacted]

TEST NO.	T(1)	T(2)	T(3)
1	1609	3818	4906
2	66184	17384	9503
3	7648	17302	3917
4	1366	3533	17391
5	1457	3473	4784
6	1551	3550	4839
7	1558	3576	4801
8	1450	3698	4818
9	1420	3777	4817
10	1467	3791	4804
11	1498	3784	4810
12	1480	3724	4782
13	1478	3685	4839
14	1404	3584	4726
15	1449	3551	4728
16	1513	3588	4789
17	1480	3639	4793
18	1450	3688	4782
19	1434	3711	4729
20	1429	3701	4707
21	1444	3680	4705
22	1468	3655	4736
23	1439	3629	4796
24	1445	3583	4710
25	1475	3613	4732
26	1464	3669	4803
27	1455	3707	4794
28	17024	3725	4808
29	1434	3688	4723
30	19330	3698	4797
31	1452	3685	4797


10
08
06
04
02
00
VOLTS
00
05
10
15
20
25
TIME IN SECONDS X 10+1
SCREEN 1 X 10+0
TEST



SCREEN 3 X 10+0
TEST


10
08
06
04
02
00
05
10
15
20
25
TIME IN SECONDS X 10+1
SCREEN 4 X 10+0
TEST

APPENDIX D

EQUIPMENT LIST

DISTRIBUTION LIST

EQUIPMENT LIST

QTY	DESCRIPTION	APPROXIMATE UNIT COST	APPROXIMATE TOTAL COST
(16)	Model 55 Ballistic Screens Oehler Research Post Office Box 9135 Austin, TX 78756	$450	$7,200
(3)	Model 4604 Counter Chronograph (ECI) Electronic Counters, Inc. Englewood, New Jersey	1,000	3,000
(1)	8K PDP 8/E Computer (DEC) Digital Equipment Corp. Maynard, MA	6,000	6,000
(1)	ASR-33 Teletype	1,200	1,200
Software:	a. FOCAL-8K 3 word variables	50	50
	b. Program listing (inclosed)		
Misc:	Interface cabling		
(4)	500 foot section of coaxial cable, 50Ω impedance	80	320
(6)	computer ribbon cable and		

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Rock Island Arsenal, Rock Island, Illinois 61201

Automatic Targeting Oevice in Support of the XM188/ XM230 Oata Acquisition Test (OAT)

Prepared By: Oennis O. Helstrom, Robert A. Peterson, and Wayne Piehl

Security Class. (of this report): UNCLASSIFIEO
Technical Report R-TR-76-046 December 1976

65 Pages, Incl Figures, Tables, Illustrations, and Appendices

This report covers the development and operating procedure for a computer operated automatic targeting device. This device automatically obtains and outputs both dispersion coordinates and velocities for an automatic weapon in bursts up to 60 rounds. The chronological order of rounds is maintained. Statistics on dispersion (and accuracy, if point of aim is input to the computer) is also output. Accuracy of this system, with 50% confidence, is within ± 1/2 inch from actual location at 1,000 inches firing 20 rounds at 2,200 ft/sec at a 600 shots per minute. The system cost is approximately $20K.

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1. Ballistic Screens
2. Computer Program (TARGET)
3. Chronographs
4. Instrumentation Interface

I. Oennis Helstrom, Robert Peterson, and Wayne Piehl
II. General Thomas J. Rodman Laboratory
III. Keith L. Ware Simulation and Experimental Firing Center

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Commander, Rock Island Arsenal
General Thomas J. Rodman Laboratory
Rock Island Arsenal, Rock Island, Illinois 61201

Automatic Targeting Oevice in Support of the XM1B8/ XM230 Oata Acquisition Test (OAT)

Prepared By: Oennis O. Helstrom, Robert A. Peterson, and Wayne Piehl

Security Class. (of this report): UNCLASSIFIEO
Technical Report R-TR-76-046 December 1976

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